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GEOSECTION INDICES FOR ENVIRONMENTAL DATA

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This publication is one of a series describing progress at the University of Wyoming in a program of research and development of "informatic" forms of data — with which the information contained in large amounts of Environmental Data can better be acquired, processed, portrayed and utilized.

The work described here has been supported largely by Contract No. E-12-70(N) of the Environmental Data Service of the Environmental Science Services Administration for an "Environmental Data Format Study" and is submitted in partial fulfillment of the terms of that Contract. The basic concepts involved were engendered in part by a discussion of the Titus World Grid for similar purposes with personnel of ESSA's Atmospheric Research Laboratories at AEC's Nevada Operations Office. They have also been developed in part in conjunction with Contract No. 14-06-D-6002 of the U. S. Bureau of Reclamation, Wyoming's Institutional Grant from the U. S. Office of Water Resources Research, and Grant No. ~~NsG658~~ NGR-51-001-001 of the National Aeronautics and Space Administration.

GEOSECTION INDICES FOR ENVIRONMENTAL DATA

INDEX

LIST OF DEFINITIONS

GEOSECTION INDICES

FOR

ENVIRONMENTAL DATA*

John C. Bellamy

ABSTRACT

A system of "geosection" index numbers is proposed herein for cross-indexing the many different kinds and growing amounts of Environmental Data. These index numbers basically identify those horizontal sections of the overall Earth-centered Geosphere to which any particular Environmental Data pertains. They thereby provide especially for identifying past and future observing stations on the surface of the Earth; and hence for ordering indexes, tabulations and files of the Environmental Data from any and all such observing stations in a widely applicable and systematically interrelated way. These "geosection" subdivisions of the Geosphere are also interchangeably representable with either the common alpha-numeric or more pictographic forms of the numerals or "indices" that comprise such index numbers.

*The work reported upon here has been supported largely by Contract No. E-12-70(N) of the Environmental Science Services Administration.

G E O S E C T I O N   I N D I C E S

F O R

E N V I R O N M E N T A L   D A T A

1. Purposes

A newly conceived system of "geosection indices" is described and proposed herein for use in indexes, tabulations and files of Environmental Data. These "geosection indices" are intended primarily to identify the Environmental Data associated with particular observing stations on the surface of the Earth in conveniently useful relationship to the horizontal positions of all other such sources of Environmental Data. They are thereby meant to provide especially for cross-indexing and interrelating the many different kinds of Environmental Data from any and all such surface observing stations.

In addition, these "geosection indices" are formulated so that they can be represented interchangeably with either phonetic alphanumeric characters or more pictographic or "informatic" forms of numerals. They thereby potentially provide for convenient manual and automatic identification and ordering of the data from individual observing stations, as well as concise pictographic representations of the horizontal distributions of environmental occurrences and data. This latter potentiality is an especially promising means of providing for more effective utilization of the ever increasing amounts of Environmental Data upon which mankind's welfare is becoming so increasingly dependent.

2. Approach

The desired characteristics of these indices have been formulated from an analytical point of view — in which the overall question to be considered can most generally be stated as being

> WHY WHO does (or should do) WHAT part of WHOSE operations (or organized activities) HOW re WHICH kinds of Environmental Data WHERE and WHEN.

The different WHICH kinds of Environmental Data of interest can then well be defined as encompassing all that exists throughout the Earth-centered or "Geospheric" region of the Universe, the major component elements of which are its

- o Solid or full-of-rocks Lithosphere,
- o Liquid or full-of-water Hydrosphere,
- o Gaseous or full-of-air Atmosphere,
- o Energetic or full-of-fiery-radiation Pyrosphere[1] (that extends to the outer limit of Earth-centered gravitational attraction at about four times the distance to the Moon-centered Lunasphere that it envelopes), and
- o Composite full-of-life Biosphere, (or that thin-shell interface at the surface of the Earth in which the four basic elements of life from the four other physical-spheres intermingle and interact to provide the basis for all of man's activities there and elsewhere).

These first-order analytic definitions serve well to clarify the overall problem at hand. On the one hand, the greatly differing nature of these five component elements of the Geosphere is clearly the basic reason WHY five WHICH and WHOSE kinds of scientific and environmental-survey disciplines tend strongly to be organized in association with the five (land, water, air, space and ecologic/social) kinds of end-use operations, largely independent of the others' more detailed WHO, WHAT, HOW, WHERE and WHEN kinds of analytic elements. On the other hand, needs to understand and deal with the interactions of all such natural spheres of interest and action are also clearly becoming ever more important and necessary. Consequently the task at hand is to help provide for as convenient coordination as possible both within and between each of these five basic kinds of Environmental Data and associated activities.

Toward analyzing this coordinating and intercoordinating problem, the term "Environmental Data" can well be defined most generally as referring to

> Environmental Data: (2.1)
>
> Any depiction or description of particular physical occurrences at specific places and times in and of the Geosphere; also, any collection of such depictions or descriptions.

The primary distinguishing feature of such Environmental Data is that the WHERE and WHEN of each such occurrence must be explicitly identified. This is to be contrasted with the more commonly familiar kinds of data with which the laboratory sciences and manufacturing technologies are usually concerned, and in which restrictions of their applicability to any particular geographic place and epoch of time are studiously avoided.

The task at hand thus consists largely of providing means of representing and, especially, indexing the WHERE and WHEN parts of Environmental Data so that both of

(1) The space-time distributions of any particular one of its WHICH kinds of occurrences and

(2) The WHERE and WHEN of all of its different WHICH kinds of occurrences

can be conveniently and usefully depicted, interrelated and analyzed.

The task at hand is more specifically to provide a conveniently useful means of <u>cross-indexing</u> the WHERE and WHEN parts of Environmental Data. For example, the WHERE of aeronautically useful Meteorological Data is most conveniently identified for many purposes with the name, radio call-letters or synoptic observing-station number of the airport to which it pertains — or from which data has been obtained by remote observation with radars or radiosondes. More agriculturally useful Climatological and Hydrologic Data, on the other hand, is conveniently identified, indexed and ordered with the names or numbers of particular climatological observing stations and stream gages. The purpose here is thus to provide for <u>cross-indexing</u> all such different WHICH kinds of Environmental Data in a more conveniently space-related and inter-relatable way.

Toward this end, this proposed method of cross-indexing is intended primarily to provide for conveniently and usefully designating that Environmental Data which can well be identified with either or both of:

(1) Particular horizontal "geosection" regions of specified horizontal angular extent and geographic position;

and

(2) Any particular Observing Station

- at which local or remote observations of occurrences anywhere in the Geosphere are originally obtained, and
- which is uniquely identified as being that one Observing Station which is located in one such suitably selected and identified "geosectional" subdivision of the Earth.

3. Background

An important example of the way in which such horizontal regions are now commonly identified is provided by the system developed by Thomas Jefferson in the early 1800's for subdividing the public lands of the United States. In brief essence, this system has been implemented by establishing some 34 "Principal Meridians" in all but the Eastern region of the United States, with respect to which Sections of land area have been established by implanting section-corner markers at (nominally) one-mile North-South and East-West intervals. Particular ones of such nominally one-mile square Sections are then designated by identifying six-by-six blocks of thirty-six such Sections with their numbers of Townships North or South and Ranges East or West, and by numbering the individual Sections in each such six-mile square "Township" in the following way.

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

NORTH

Smaller area subdivisions of each such Section are then identified as being its NW, NE, SW or SE Quarter, or even smaller (nominally 40 acre) areas as being the NW, NE, SW or SE Quarter of one of those larger (nominally 160 acre) Quarters. Typically, a particular 40 acre plot might thereby be identified as being the

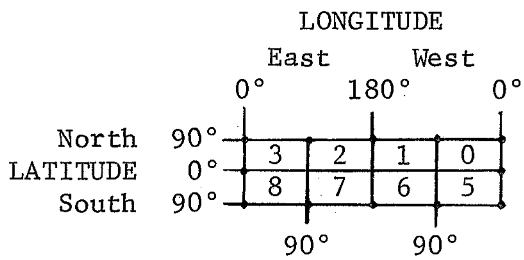
"SW 1/4 of the NE 1/4 of Section 33, T16N, R73W
of the Sixth Principal Meridian."

A somewhat similar technique was devised by Admiral Marsden in the early 1800's for identifying particular horizontal regions of oceanic areas[2]. In this case the basic unit of area is a 10° Latitude by 10° Longitude "Marsden Square". Particular ones of such Marsden Squares are identified with three decimal-digit numbers that are ordered in East to West progression along the 10° tiers of Latitude as indicated in the following schematic diagram.

		East			LONGITUDE			West	
		0° – 10°	10° – 20°		180°			20° – 10°	10° – 0°
	90° – 80°	936	935		919	918		902	901
	80° – 70°	288	287		271	270		254	253
	70° – 60°	252	251		235	234		218	217
North	60° – 50°	216	215		199	198		182	181
	50° – 40°	180	179		163	162		146	145
	40° – 30°	144	143		127	126		110	109
	30° – 20°	108	107		091	090		074	073
	20° – 10°	072	071		055	054		038	037
LATITUDE	10° – 0°	036	035		019	018		002	001
	0° – 10°	335	334		318	317		301	300
	10° – 20°	371	370		354	353		337	336
	20° – 30°	407	406		390	389		373	372
	30° – 40°	443	442		426	425		409	408
South	40° – 50°	479	478		462	461		445	444
	50° – 60°	515	514		498	497		481	480
	60° – 70°	551	550		534	533		517	516
	70° – 80°	587	586		570	569		553	552
	80° – 90°	623	622		606	605		589	588

Each such Marsden Square is then subdivided into 1° Latitude by 1° Longitude Sub-Squares, particular ones of which are identified by the two decimal-digit numerals of the 1° digits of the Latitude and Longitude numbers of their Equatorward and Greenwich-ward boundary lines, respectively. Larger (either 2°x2° or 5°x5°) Sub-Squares can also be identified when desired in the Marsden System with the code number of the 1°x1° subdivision of the larger square that is closest to the Equator and the Greenwich Meridian.

Alternatively, 0.1° Latitude by 0.1° Longitude unit-regions of oceanic areas are also frequently identified[2] with a seven decimal-digit "Octant Code" QLaLaLaLoLoLo in which LaLaLa and LoLoLo stand for the numerals of the 10°, 1° and 0.1° digits of the Latitude and Longitude numbers of the Equatorward and Greenwich-ward boundary of any one such region. In this system Q stands for a numeral that identifies a particular Octant of the Earth in accordance with



For filing purposes this Octant Code is frequently shortened to the three digit code number QLaLo, in which La and Lo stand for the numerals of the 10° digits of the Latitude and Longitude numbers of the Equatorward and Greenwich-ward boundary lines of 10°x10° "squares", respectively.

Another indexing system of this kind has recently been introduced by Titus[3] more for identifying particular Surface Observing Stations in particular unit-regions on land than those regions in and of themselves. The outstanding characteristic of this Titus World Grid system is that it utilizes digital radixes of 24, 25 and 26 (in which the digital numerals are the letters of the alphabet) for numbering successively smaller Latitude-by-Longitude "squares" in order to reduce the required number of digits. Explicitly, it utilizes a nine numeral code-symbol in which letters of the alphabet identify, in left to right order, one of the successive:

(1) 26° West Longitude intervals from the 0°-26° A-interval through the fourteenth such (partial) 338°-360° N-interval;

(2) 1° Westerly ordered subintervals of Longitude from the 0°-1° A-subinterval through the twenty-sixth such 25°-26° Z-subinterval;

(3) 26° Latitude intervals in accordance with

```
          South          North
    90°_78°_52°_26°_0°_26°_52°_78°_90°
       V   U   T   S  W   X   Y   Z
```

(4) 1° Polewardly ordered subintervals of Latitude from the 0°-1° A-subinterval through the twenty-sixth such 25°-26° Z-subinterval;

(5) 2.5' Westerly ordered subintervals of the 1° Longitude intervals from the 0'-2.5' A-subinterval through the twenty-fourth such 57.5'-60' X-subinterval;

(6) 2.5' Polewardly ordered subintervals of the 1° Latitude intervals from the 0'-2.5' A-subinterval through the twenty-fourth such 57.5'-60' X-subinterval;

(7) 0.1' Westerly ordered subintervals of the 2.5' Longitude intervals from the 0.0'-0.1' A-subinterval through the twenty-fifth such 59.9'-60' X-subinterval;

(8) 0.1' Polewardly ordered subintervals of the 2.5' Latitude intervals from the 0.0'-0.1' A-subinterval through the twenty-fifth such 59.9'-60' X-subinterval;

and in which a 9th indexing numeral consisting of the Arabic numerals 1,2,3,4 or 5 is used to identify one of equal area subdivisions in the SE, SW, NW and NE corners and center of any particular one of the 8th order 0.1'x0.1' unit-regions.

4. Definition of "Geosection"

It is significant that two quite different kinds of horizontal areas are identified by these common indexing systems. On the one hand, Jefferson's method is intended primarily to subdivide the public lands into as nearly equal-area and "square-with-the-world" plots of land as possible on the spheroidal Earth. In contrast, the Marsden and Octant systems are intended primarily to identify horizontal positions in close association with the numbers of Latitude and Longitude with which the positions of ships at sea can most readily be determined. The Titus system, on the other hand, is intended primarily to identify as nearly equal-area regions as practicable on the land, and essentially utilizes Latitude and Longitude numbers as a fully intercoordinated and conveniently useful approximate means of doing so anywhere and everywhere throughout the world.

It is also important in this regard to notice that the overall indexing task at hand involves the coordination and intercoordination of both of the WHERE and WHEN aspects of Environmental Data; and that its WHEN aspects are intimately associated with Longitudinal positions on the Earth. Basically, most physical occurrences and human activities throughout the Geosphere are either controlled or strongly affected by the diurnal risings and settings of the Sun. Epochal times are thus most widely and usefully expressed in terms of various kinds of Mean Solar Time, of which the Longitudinally-dependent Local Mean Solar Time is of greatest direct physical significance for any particular Longitudinal position on the Earth.

The Marsden, Octant and Titus kinds of "squares" are thus seen to provide for cross-indexing the horizontal positions of Environmental Data in coordinative relationship to both areal and temporal considerations. The name "square" is not, however, very descriptively appropriate for unit-regions that approach the shape of triangles at the poles. Rather, "geosection" is proposed here as a more appropriate generic name for any and all scale-sizes of such unit-subdivisions or "sections" of the horizontal extent of the "geo-" Earth in accordance with the following formal definition.

<u>Geosection</u>: (4.1)

Any unit angular-area subdivision of the horizontal extent of the Earth-centered Geosphere that encompasses a prescribed unit of angle interval, $U'\alpha$, of both of Latitude, φ, and Longitude, λ,

- o Such that cardinal-number measures $(\varphi/U'\alpha)$ and $(\lambda/U'\alpha)$ of the Latitude and Longitude of any and all points within a particular geosection are contained in the range of numbers

  $$[\varphi/U'\alpha] \leq (\varphi/U'\alpha) < [\varphi/U'\alpha] + 1$$

  and $$[\lambda/U'\alpha] \leq (\lambda/U'\alpha) < [\lambda/U'\alpha] + 1$$

  in which $[\varphi/U'\alpha]$ and $[\lambda/U'\alpha]$ are the prescribed integral, ordinal-number counts with which successive ones of like unit-intervals $U'\alpha$ of φ and λ are identified,

  and

- o Such that the unit angular interval, $U'\alpha \equiv [U]C'\alpha$ is a prescribed integral-number fraction $[U]$ of 1 Circle of Angle, $C'\alpha$.

This "geosection" name also connotes a useful qualitative relationship of the particular 1-minute of Latitude by 1-minute of Longitude (or $U'\alpha = 1'$) scale-size of geosections with the 1-mile square "Section" of the public lands. It is especially interesting in this cross-coordination regard that Jefferson unsuccessfully proposed[4] in 1784 that the "geographic" or "as nearly one-minute of latitude as practicable" nautical kind of mile (rather than the more personally than Earth-related 5,280 foot or about 15% smaller "statute" kind of mile) be so utilized on land as well as at sea.

It is also important in this regard to recognize the existence of two basically different kinds of Latitude and Longitude. On the one hand, the "Geodetic" kind of Latitude and Longitude is utilized primarily to coordinate features of and on the land with respect to linear measures of horizontal distances between them. On the other hand, the "Astronomical" kind of Latitude and Longitude of any point on the Earth is directly determinable, entirely independent of any such distance measurements, by observing the angular positions of the stars in accordance with the following formal definitions.

<u>Astronomical</u> <u>Latitude</u>, $\underline{\varphi}$: (4.2)

An angular coordinate of horizontal North-South positions on or near the Earth's surface;

The right-angle complement of the angle between

- o The zenith direction of a plumb-line at rest with respect to the solid Earth at a particular point on or near its surface

  and

- o The line of sight from that point to the apparent center of rotation of the stars.

<u>Astronomical</u> <u>Longitude</u>, $\underline{\lambda}$: (4.3)

An angular East-West coordinate of horizontal positions on or near the Earth's surface;

The dihedral angle measured around the axial line of sight to the apparent center of rotation of the stars between

- o The plane of the local meridian formed by that axial line of sight and the direction of a plumb-line at rest with respect to the solid Earth

  and

- o The plane of the line of sight to a star at the instant of time that it is traversing the zero-longitude meridian of the Greenwich Observatory.

It is fundamentally impossible, however, for any single set of Latitude and Longitude numbers to correspond exactly to both such distance and angular measures. Rather, the "Geodetic" kinds of coordinates are basically defined by assigning particular Latitude and Longitude numbers to the bench-marks of precise triangulation surveys, and by selecting those bench-mark numbers so that they minimize the residuals of such distance and angular measurements from usefully idealized mathematical models of their interrelationships. Measurements of the "station error" residuals between these Geodetic and Astronomical kinds of Latitude and Longitude have been found[5] to be as much as 30 seconds of arc only in exceptional instances, and to be much less than this throughout most of the world.

Practically, Definition 4.1 of "Geosection" can then well be specified to refer to:

- o Astronomical Latitude and Longitude throughout the oceanic and any other regions of the world in which precise geodetic surveys are not available; and
- o Geodetic Latitude and Longitude in those regions that are traversed by precise triangulation surveys (and which thereby provide for readily resolving the relative horizontal positions of geospheric occurrences throughout such regions to the order of one thousandth of a second of arc or one tenth of a foot).

It is then only necessary to identify which kind of Latitude and Longitude is being utilized in any particular instance, and to interrelate them with geodetic survey data concerning their residual differences only in those rare instances that extreme precision is required, significant and possible.

5. Sizes of Geosections

The preceding contemporary methods of indexing horizontal regions of the Earth also clearly reflect a strong need to be able to select and utilize whatever scale-size of Geosection might best serve some particular purpose. For example, the way in which the public lands are subdivided provide for conveniently identifying whichever of a thirty-six square mile Township, a one square-mile Section, a quarter-Section or a sixteenth-Section might be most appropriately useful for some particular purpose. Similarly, the Marsden system explicitly provides for identifying whichever of a 10°x10°, 5°x5°, 2°x2° or 1°x1° size of geosections might be most useful in a particular instance; the Octant system provides for identifying any one of 0.1°x0.1°, 1°x1°, 10°x10° or 90°x90° sizes of geosections; and the Titus World Grid system essentially provides for identifying the $U'\alpha$ = 1° size of geosections with its first four numerals, the $U'\alpha$ = 2.5' size of geosections with its first six numerals, or the $U'\alpha$ = 0.1' = 6" size of geosections with its first eight numerals.

A useful basic procedure for establishing different coordinated sizes of Geosections is thereby seen to be:

First, to subdivide the entire horizontal extent of the Earth into major first-order Geosections such as its Octants or its 10°x10° Marsden Squares;

Second, to subdivide those first-order Geosections into smaller second-order Geosections such as the 10°x10° subdivisions of Octants or the 5°x5°, 2°x2° or 1°x1° subdivisions of the Marsden Squares;

Third, to subdivide each such second-order Geosection into smaller third-order Geosections;

and so forth until, but necessarily only until, sufficient resolution of horizontal positions has been achieved to serve the needs of a particular purpose.

In general, this subdivisional process needs to be continued for any particular WHICH kind of Environmental Data until the occurrences or activities that it represents are representative of those that occur throughout the smallest of such successively smaller geosections. As illustrated by the Titus World Grid, for example, this limiting scale-size for the meso-scale atmospheric phenomena of interest in the Nevada Test Site is evidently of the order of the approximately 3 angular-second or 300 foot size of the regions that are identified by its ninth indexing numeral. For most climatological and synoptic meteorological data, on the other hand, that smallest representative size is presumably of the order of the $U'\alpha = 1$ minute of arc to which the listings of the Latitude and Longitude of their observing stations are commonly resolved.

The common degree, minute and second units of Latitude and Longitude angles provide an exceptionally useful systematic basis for subdividing the Earth into highly selectable and fully intercoordinated sizes of geosections. Toward this end, a limited set of "Primary Unit Sizes of Geosections" can well be identified at the outset as being those for which

$U'\alpha = [1/6]C'\alpha = 60°$ or one sextile
$U'\alpha = [1/6\cdot 60]C'\alpha = [1/360]C'\alpha = 1°$ or one degree,
$U'\alpha = [1/360\cdot 60]C'\alpha = 1'$ or one angular-minute, and
$U'\alpha = [1/360\cdot 60\cdot 60]C'\alpha = 1''$ or one angular-second.

These particular Primary sizes of geosections are characteristically interrelated by the scaling-factor of 60, which in turn has an exceptionally large number of integral-number subdivisions (into any one of 1,2,3,4,5,6,10,12,15,20,30 and 60 sets of equal linear sub-sizes).

Consequently they provide for selecting and conveniently identifying an exceptionally large number of intermediate sizes of geosections which can well be:

- Representative of the characteristic scale-size of any one particular WHICH kind of occurrence, phenomenon or activity of particular interest in and of the Geosphere,
- Made up of an integral number of whatever smaller fractions of whatever smaller Primary Unit Sizes of geosections might have been so-selected for identifying, ordering and analyzing other scale-sizes and WHICH kinds of geospheric occurrences; and at the same time
- Readily combinable into whichever of their integral number multiples might have been selected for summarizing, filing, ordering, indexing and/or analyzing the same as well as other WHICH kinds of Environmental Data.

Significantly in this regard, the Geodetic Latitude and Longitude of triangulation survey bench-marks are typically assigned numbers of degrees, minutes, seconds, and tenths, hundredths and thousandths of seconds of arc. Consequently it is conveniently possible to determine and express the horizontal positions of even the smallest scale-sizes of geospheric occurrences in full coordinative relationship to the scale-sizes and positions of all others throughout the world. To do so, it is only necessary

(1) To tie distance and direction surveys of the relative horizontal positions of observation points to those triangulation station bench marks;

(2) To convert such measures of horizontal distances and directions to corresponding angular numbers of Geodetic Latitude and Longitude;

and

(3) To consider the residual differences (of at most about 30 seconds of arc) between the Geodetic and Astronomical kinds of Latitude and Longitude in those rare cases that extremely precise coordination of widely separated occurrences is required.

It is also significant in this regard that a newly formulated[6] "Geospheric System of Units" provides for exceptionally convenient and useful intercoordination of such horizontal distance measurements and corresponding lengths of geodetic arcs. That intercoordination is provided by the simple expedient of identifying "geounits" of length with symbols such as $U'L \equiv [U]C'L$; and by defining them to be the same numerical fraction [U] of an ideally assigned Earth-circumference C'L of 40,000,000 meters with which any similarly U-scaled unit of angle, $U'\alpha \equiv [U]C'\alpha$, is defined to be that [U] fraction of the circle of angle, $C'\alpha$. The basic reference or Primary Scale-Sizes of such "coordinal" or "as nearly equivalent as practicable" geounits of horizontal angular arcs and linear distances thereby consist of

For [U] = [X] = 1/6
1 $X'\alpha$ = 1 sextile of angle or 1 "sextang" and
1 X'L = 1 sextile of length or 1 "sextile" of exactly 3,600 "geomiles"

For [U] = [D] = 1/6(60),
1 $D'\alpha$ = 1 degree of angle or 1 "dang" and
1 D'L = 1 "dile" of exactly 60 "geomiles";

For [U] = [M] = 1/6(60)(60),
1 $M'\alpha$ = 1 minute of angle or 1 "mang" and
1 M'L = 1 "(geo-)mile" or very slightly altered "nautical mile";

For [U] = [S] = 1/6(60)(60)(60),
1 $S'\alpha$ = 1 second of angle or 1 "sang" and
1 S'L = 1 "sile" or 1/60 "geomiles" or 100 "geofeet";

For [U] = [F] = 1/6(60)(60)(60)(100),
1 $F'\alpha$ = 0.01 seconds of angle or 1 "fang" and
1 F'L = 1 "file" or 1 "geofoot" of exactly 1/6000 "geomiles";

For [U] = [T] = 1/6(60)(60)(60)(100)(12),
1 $T'\alpha$ = 1/1200 seconds of angle or 1 "thang" and
1 T'L = 1 "thile", 1 "thumb-width" or 1 "geoinch" of exactly 1/12 "geofoot" or "file".

These "geounits" of angle and length provide the extreme convenience of interpreting, at will, the identifying numbers of geosections as representing either angular or linear positions and distances on the surface of the Earth. Measurements of these two kinds of numbers of angular and linear distances along particular horizontal arcs throughout the world have been found[7] to differ by the order of at most plus or minus 5 parts per 1000 near the Equator and the Poles, and by much less than this in middle latitudes. Consequently it is only in extremely rare instances that such deviations from their first-order interconversion factor of UNITY need be considered in determinations of the positions of points in the vicinity of and with respect to the precisely determined Latitude and Longitude positions of triangulation survey benchmarks.

In addition, these geounits of length are closely related to the widely familiar and useful "nautical" mile and "statute" foot. The current International Nautical Mile is defined to be exactly equivalent to 1,852 meters in comparison to the more consistently and simply defined 100/54 kilometer or 1,851.851··· meter "geomile". Similarly, the "statute" foot is currently defined to be exactly equivalent to 0.3048 meters, or only about 1 part in 80 smaller than (or the exactly $0.98755\dot{2}$ fraction of) the more conveniently Earth-related "geofoot" or "file" of exactly 1/3.24 meters. Consequently numbers of angular distances can well be considered for most purposes as also representing corresponding numbers of either the "nautical" or "geo-" kinds of miles and "statute" or "geo-" kinds of feet; and the "geo-" kinds of miles and feet can well be utilized whenever a more consistently interpretable and precise conversion might be required.

6. Alpha-Numeric Geosection Indices

Particular ones of particular scale-sizes of such geosections can then evidently well be identified with code-symbols or a generalized kind of Index Number such as $I_1 I_2 I_3 \cdots I_i \cdots$ in which:

- o The first, second, third, etc., place-positions of the indices I_1, I_2, I_3, etc., refer in sequential order to the first, second, third, etc., order of successively smaller subdivisions of the overall horizontal extent of the Geosphere; and
- o The particular character that stands in the place of any particular one of the I_i symbols identifies a particular one of that i-th order size of geosections into which a particular one of the next larger or (i-1)th order of geosections has been subdivided.

It is specifically proposed here that this successive subdivisional process can well be initiated by first subdividing the horizontal extent of the Earth into its eighteen 60° by 60° Sextiles, and by identifying each such Sextile with a letter of the alphabet in accordance with the following schematic table.

Alpha-Numeric Indices of Sextiles (6.1a)

LONGITUDE

180° West 0° East 180°

						90°
A	B	C	D	E	F	30° North
G	H	I	J	K	L	30° LATITUDE
M	N	O	P	Q	R	90° South

0^h 12^h 24^h

LOCAL TIME OF A DAY

Each such Sextile can then well be subdivided into whichever of the following four different second-order sizes of geosections might best serve some particular purpose.

2x2 Alpha-Numeric Subdivisions of Geosections (6.1b)

W	X
Y	Z

↑ North

3x3 Alpha-Numeric Subdivisions of Geosections (6.1c)

1	2	3
4	5	6
7	8	9

↑ North

4x4 Alpha-Numeric Subdivisions of Geosections (6.1d)

A	B	C	D
F	G	H	I
K	M	N	O
Q	R	S	T

↑ North

in which the sub-geosections are assigned the same letters as the NW 4x4 block of 5x5 subdivisions to simplify their memorization.

5x5 Alpha-Numeric Subdivisions of Geosections (6.1e)

a	b	c	d	e
f	g	h	i	j
k	m	n	o	p
q	r	s	t	u
v	w	x	y	z

↑ North

in which the letter l has been omitted to avoid confusion with the numeral 1.

Each of any such second-order geosections can then well be subdivided into whichever of these 2x2, 3x3, 4x4 or 5x5 kinds of third-order subdivisions would best serve that particular purpose, and so forth until the desired degree of resolution has been achieved. For example, the sequence of alpha-numeric indices AD7z would thereby identify that geosection which is the

z or most South-Easterly of the 1° by 1° or 5x5 subdivisions of the

7 or most South-Westerly of the 5° by 5° or 3x3 subdivisions of the

D or most North-Easterly of the 15° by 15° or 4x4 subdivisions of the

A 60°x60° Sextile, which is bounded by the 30° and 90° parallels of North Latitude and the 120° and 180° meridians of West Longitude.

This particular procedure has been selected primarily to take full systematic advantage of the highly subdivisible characteristics of the scaling factor of $60 = (3)(2)^2(5)$ among the sextile, degree, minute and second units of Latitude and Longitude angles. It essentially does so by providing a convenient means of successively subdividing any such factor of 60 into whatever order of successive 2, 3, 4 and 5 subdivisions might best serve some particular purpose. It also utilizes distinctive (Arabic Numeral, Upper-Case Letter and Lower-Case Letter) symbols to identify the particular one of 2-, 3-, 4- or 5-time kinds of subdivisions to which they pertain — irrespective of the order in which they might have been formulated at the free will of the originator of any particular index number.

This procedure also utilizes the serial numbering procedure with which particular ones of a particular scale-size of geosections are identified in much the same way that the Sections of public land, Octants and Marsden Squares are numbered. The advantage of doing so is that each of the geosections of any one particular size can thereby be simply and uniformly identified with a single symbol. In contrast, the orthogonal pairs of numbers with which the subdivisions of Octants, Marsden Squares and Titus geosections are identified require the simultaneous consideration and cross-correlation of two separate and largely independent symbols and numbering systems. The serial numbering system also provides for typing and printing lists of geosection index numbers without irregular spacings or redundant insertions of spacing-zeros, as well as explicit self-contained indications of the number of successive subdivisions into which the Earth has been divided in any particular and highly selectable instance.

This serial method of numbering also provides for utilizing the letters of the alphabet as numerals of ordinal-numbering systems with digital radixes of 16, 18 and/or 25; and as in the Titus World Grid, for thereby reducing the number of numerals required to identify a particular geosection. In comparative example, 1° by 1° geosections can be identified with

- 4 of these geosection indices such as AD7z,
- 4 Titus-system indices such as FAYX,
- 5 Marsden Square indices such as 26650, or
- 5 Octant system indices such as 17530, whereas
- 10 numeral spaces are required for a listing such as 75°N, 13°W of the Equatorward and Greenwich-ward corner of that particular 1° by 1° geosection.

Even more dramatically, only 10 such geosection indices are needed to index any 1" by 1" geosection in comparison to the 22 letter-spaces required for a listing such as XX°XX'XX"N of Latitude and XXX°XX'XX"W of Longitude.

The serial order of successive geosections of any one size specified in Definition 6.1 has in turn been selected primarily from an end-use point of view — in which it is recognized that by far their greatest end-use is to order, index and identify typewritten or printed descriptions or tabulations of Environmental Data. Consequently they have been ordered in the same way that such descriptions and tabulations are most commonly ordered; namely from left to right across horizontal lines in a top to bottom succession of lines, or hence from West to East across successive tiers of Geosections in a North to South progression of those tiers.

The way in which the Sextiles are identified in Definition 6.1a has also been selected from considerations of the intimate relationship between Longitude and Times of the Day. That is, there is only one instant of time each day (at Greenwich Noon) that Local Times throughout the world have the same Day-Number. Consequently it is both possible and logical to utilize the Longitude subdivisions of the Earth to reflect the corresponding time-divisions of a day that are occurring locally at that instant of time throughout the world as specified in Definition 6.1a.

7. Pictographic Geosection Indices

These alpha-numeric indices are not as conveniently useful as they might well be, however, in other important respects. They especially do not provide — in and of themselves — a directly interpretable picture of the relative geographic positions of the geosections that they represent. Neither do they provide for nearly as useful automatic sensing and interpretation as they well might. Rather, such alpha-numeric numerals frequently need to be translated into other forms of numerals such as:

- Graphical plots of their relative positions as "dots" or "station circles" at particular positions with respect to the grid lines of some sort of a pictorial projection or map of the Earth's surface;

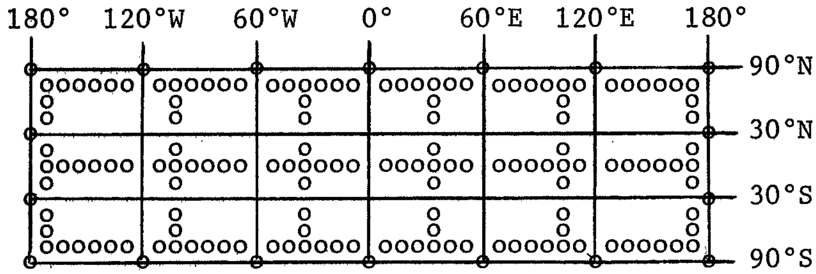
  as well as

- Some sort of punched holes or magnetic states in ordered arrays of "dots" or "bits" on punched cards or magnetic tapes that can be more readily sensed and processed by automatic data processing machines.

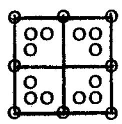
The preceding system of subdividing the Earth into successively smaller-scale geosections also lends itself, however, to a potentially very useful way to serve both of these other kinds of purposes. It has been selected in large part to provide for the use of the following pictographic forms of numerals which, by virtue of being composed of simply ordered arrays of dots, are also potentially capable of being readily recorded and recognized automatically.

Pictographic Geosection Indices (7.1)

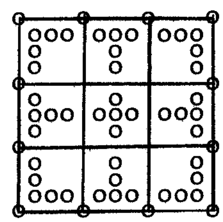
60°x60° Sextiles:



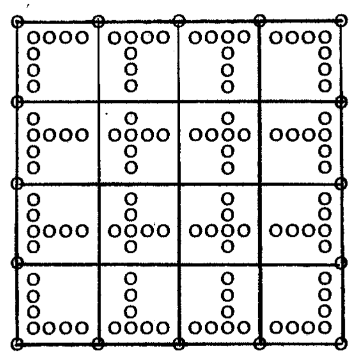
2x2 or "Quarter" Subdivisions:



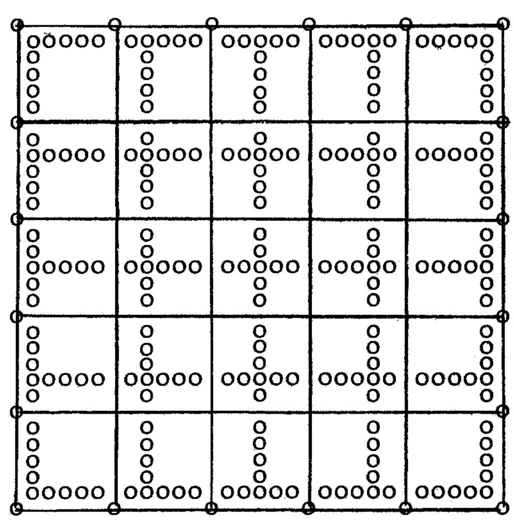
3x3 or "Ninth" Subdivisions:



4x4 or "Sixteenth" Subdivisions:



5x5 or "Twentyfifth" Subdivisions:



These pictographic numerals have been designed so that they clearly identify both of

- o The numbers of sub-geosections into which any larger geosection has been subdivided by the numbers of dots that have been included in their horizontal or East-West and vertical or North-South rows of dots, and
- o That particular one of such smaller scale geosections that occurs at the position represented by the intersection of the horizontal and vertical rows of dots.

For example, that 1° by 1° geosection which has previously been identified with the alpha-numeric index number AD7z can thereby well be identified with the synonymous pictographic numerals

```
oooooo  oooo  o        o
o          o  o        o
o          o  ooo      o
           o           o
                   ooooo
```

These symbols directly identify this particular geosection as being "the most south-easterly twentyfifth of the most south-westerly ninth of the most north-easterly sixteenth of the most north-westerly Sextile."

The outstandingly useful characteristic of these pictographic numerals is that they provide a directly interpretable "picture" of the relative scale-size and position of any particular geosection relative to all other geosections — all without having to remember any arbitrary naming and ordering conventions other than that

- o North is toward the top and East is toward the left of the symbols, and
- o The first-order (Sextile) subdivision of the entire Earth is centered between the Date-Line Meridians and the Poles.

Indeed, these pictographic numerals are little more than short-hand abbreviations of those diagrams with which the naming and ordering conventions of any other kinds of indices such as the alpha-numeric numerals of Definition 6.1 usually need to be illustrated.

These pictographic numerals suffer the disadvantage in and of themselves, however, that it is difficult to "pronounce" them either to someone else or in one's own thinking process. It might become possible with frequent and continued use to translate them into their synonymous alpha-numeric "names", or even into corresponding numbers of degree, minute and second measures of Latitude and Longitude. However, the continual mental strain of such translations clearly should be avoided, and well can be by assigning the following "phonetic names" to the relative positions of geosections that are indicated by the pictographic numerals.

Phonetic Names of Pictographic Indices (7.2)

onety-first	onety-second	onety-third	onety-fourth	onety-fifth	onety-sixth
twenty-first	twenty-second	twenty-third	twenty-fourth	twenty-fifth	twenty-sixth
thirty-first	thirty-second	thirty-third	thirty-fourth	thirty-fifth	thirty-sixth
forty-first	forty-second	forty-third	forty-fourth	forty-fifth	
fifty-first	fifty-second	fifty-third	fifty-fourth	fifty-fifth	

Specifically, these "phonetic names" of the pictographic numerals have been formulated in accordance with the convention that

- East-West rows of sub-sections are systematically assigned the names "onety", twenty, thirty, forty and fifty in top to bottom or hence North to South succession, and
- North-South columns of sub-sections are assigned the ordinal-number names first, second, third, fourth, fifth and sixth in left to right or hence West to East succession.

For example, the pictographic index number

```
oooooo  oooo   o        o
o          o   o        o
o          o   ooo      o
           o            o
                    ooooo
```

can thereby be "read" directly as being the

"fifty-fifth of the twentyfifth-part subdivisions of the thirty-first of the ninth-part subdivisions of the onety-fourth of the sixteenth-part subdivisions of the onety-first Sextile"

or, whenever the particular order of subdivision is known, merely as

"Geosection number onety-one, onety-four, thirty-one, fifty-five."

It is noteworthy that these samples of pictographic numerals are much larger in this descriptive and definitive discussion than they well could be in routine use. For example, their individual dots could readily be reduced to the size of 1 printer's point (or 1/72 of an inch), thereby reducing the space required by a 5x5 pictographic numeral to about 6x6 points or 1/12 of an inch square. A more easily discernible overall size of pictographic numerals might well prove to be twice as big as that, or equivalent to two of the 1/12 by 1/6 inch spaces allotted to each character of the "elite" size of typewriting, or to one third of their linear size in this discussion.

These pictographic numerals have also been designed so that they are potentially easy to record and playback automatically. For example, the 72 different pictographic characters of Definition 7.1 might well be produced with a special type-ball of the selectric kind of typewriter. Alternatively, they are potentially recordable with a dot-matrix kind of recorder — in which case a 5x6 matrix would suffice and the programming of only appropriate rows and columns of dots would be much simpler than, for example, programming for alpha-numeric characters. Conversely, automatic optical sensing and pattern recognition of only rows and columns of dots are potentially much simpler, less expensive and more reliable than the automatic recognition of alphanumeric characters.

8. Standard Geosection Index Numbers

These pictographic forms of geosection indices are expected to be most useful for cross-indexing the horizontal positions of large amounts of particular WHICH kinds of Environmental Data in conjunction with map-like portrayals of their space-time distributions. The ability to select and use whichever sequence of successive 2, 3, 4 or 5 fractional subdivisions of any particular region might best portray the characteristic features of that particular WHICH kind of geospheric occurrences is expected to prove to be especially useful for such purposes.

The quite different purpose of providing for the intercoordination of all different WHICH kinds of Environmental Data, on the other hand, tends strongly to limit the freedom of choice of geosection scale-sizes. It is highly desirable for this purpose to index, order and file any and all different WHICH kinds of Environmental Data with exactly the same system of index numbers. And at least for many years to come, the alpha-numeric form of geosection indices and/or their standardized punched card, punched tape or magnetic tape counterparts are likely to prove to be much more conveniently useful for such cross-filing purposes.

Toward resolving these conflicting requirements, at least one of the sizes of geosections that might be used for some pictographic purpose could always well be selected as being one of the primary degree, minute or second scale-sizes of geosections. This policy would still provide for considerable freedom of choice of those intermediate scale-sizes that are most characteristically useful for portraying particular kinds of geospheric occurrences. It would at the same time provide at least one common reference scale for intercoordinating horizontal positions among all different WHICH kinds of such data-portrayals.

In addition, the following standard sequence of subdivisions of the horizontal extent of the geosphere can well be adopted for cross-indexing the relative positions of any and all WHICH kinds of Environmental Data with alpha-numeric indices.

<u>Standard Geosection Index Numbers</u> (8.1)

Sequential arrays of alpha-numeric or pictographic indices, $I_1, I_2, I_3 \cdots I_n$, that identify particular ones of the following order and size of successive geosection subdivisions of the horizontal extent of the Earth:

	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9	I_{10}
	oooooo oooooo oooooo	oooo oooo oooo oooo	ooo ooo ooo	ooooo ooooo ooooo ooooo ooooo	oooo oooo oooo oooo	ooo ooo ooo	ooooo ooooo ooooo ooooo ooooo	oooo oooo oooo oooo	ooo ooo ooo	ooooo ooooo ooooo ooooo ooooo
$U'\alpha=$	$60°$	$15°$	$5°$	$1°$	$15'$	$5'$	$1'$	$15''$	$5''$	$1''$
$U'\alpha=$	4^h	1^h	20^m	4^m	1^m	20^s	4^s	1^s	20^c	4^c

This particular order of sequential subdivision has been selected primarily to provide for the convenient whole-number relationship to local times of the day indicated in Definition 6.1a and the last line of Definition 8.1. It is significant in this regard that the systematic 60-part subdivisions of time-like units of angle continue beyond the second of time to the period of the 60 cycle per second frequency of alternating current, c, with which electrical clocks are commonly synchronized. Consequently this standard subdivisional process could well be continued (in those rare instances that such an extremely fine resolution of the entire extent of the Earth as to the order of the

$F'\alpha$ or geofoot-like and $T'\alpha$ or geoinch-like units of angle might be useful) in accordance with:

	I_{11}	I_{12}	I_{13}	I_{14}	I_{15}
	oooo oooo oooo oooo	ooooo ooooo ooooo ooooo ooooo	ooooo ooooo ooooo ooooo ooooo	ooo ooo ooo	oooo oooo oooo oooo
$U'\alpha =$	0.25"	0.05"	0.01"	(1/300)"	(1/1200)"
$U'\alpha =$	1^c	0.2^c	0.04^c		
$U'\alpha =$	$25F'\alpha$	$5F'\alpha$	$1F'\alpha$	$4T'\alpha$	$1T'\alpha$

The alpha-numeric form of Index Numbers for such extremely small Geosections would then look like the Index Number

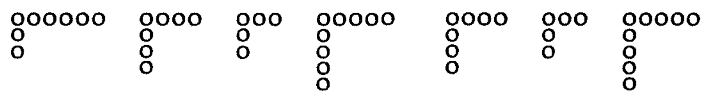
AA1aA1aA1aAaa1A
AA1a A1a A1a Aaa1A
or AA1A A1A A1A AAA1A

for that most northwesterly Geosection which extends one inch (or only one thumbwidth!) southward from the North Pole along the Date-Line Meridian. The third of these alternatives would be used if both upper and lower case letters were not available. The spaces of the second and third alternatives serve well to help identify each successive order of subdivision with respect to the Primary Degree, Minute and Second scales of subdivision.

This extreme degree of resolution to the order of each "square inch" of the Earth's surface can actually be realized in those regions in which the Latitudes and Longitudes of triangulation survey bench-marks are assigned values to the thousandth part of a second of arc or to the tenth part of a geofoot. In the vast majority of uses, however, it suffices to identify the positions of Observing Stations with much shorter index numbers. For example, the needs of synoptic-scale and much of meso-scale meteorology can well be served with seven digit index numbers such as

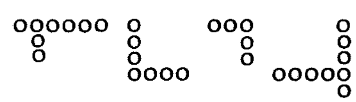
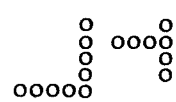
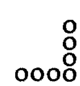
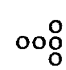
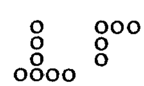
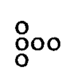
AA1aA1a
AA1a A1a
AA1A A1A

or



for that most northwesterly Geosection that extends 1 minute or 1 geomile southward from the North Pole along the Date-Line Meridian.

Indeed, it is frequently desirable to use only as many indices as are required to uniquely identify each station in any particular listing of Environmental Data. For example, the originating stations of the generalized analysis kinds of Environmental Data such as this paper can well be identified with Universities. The locale of all Universities could then well be cross-indexed with respect to each other (as well as all other WHICH kinds of Environmental Data) as in the following alphabetically-ordered listing of the uniquely differing Standard Geosection Index Numbers and Pictographic Indices of a few of them.

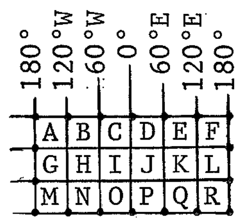
University of Wyoming Laramie	BQ3u	
Colorado State University Fort Collins	BQ3zI	
Colorado University Boulder	BQ3zT	
Colorado School of Mines Golden	BQ6e	
University of Northern Colorado, Greeley	BR1v	
Denver University Denver, Colorado	BR4a	

In conclusion, the alpha-numeric indices (and, by positional inference, the pictographic indices) of such Standard Geosection Index Numbers are explicitly identified in the following Definition 8.2. Hopefully this definition and all that it implies will be found by others to be as widely useful as they promise to be for indexing and cross-indexing any and all kinds of Environmental Data and associated activities throughout the Geosphere.

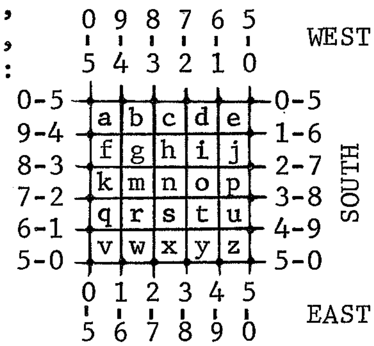
Standard Geosection Indices (8.2)

I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9	I_{10}	of the following
60°	15°	5°	1°	15'	5'	1'	15"	5"	1"	successive sizes of geosections:

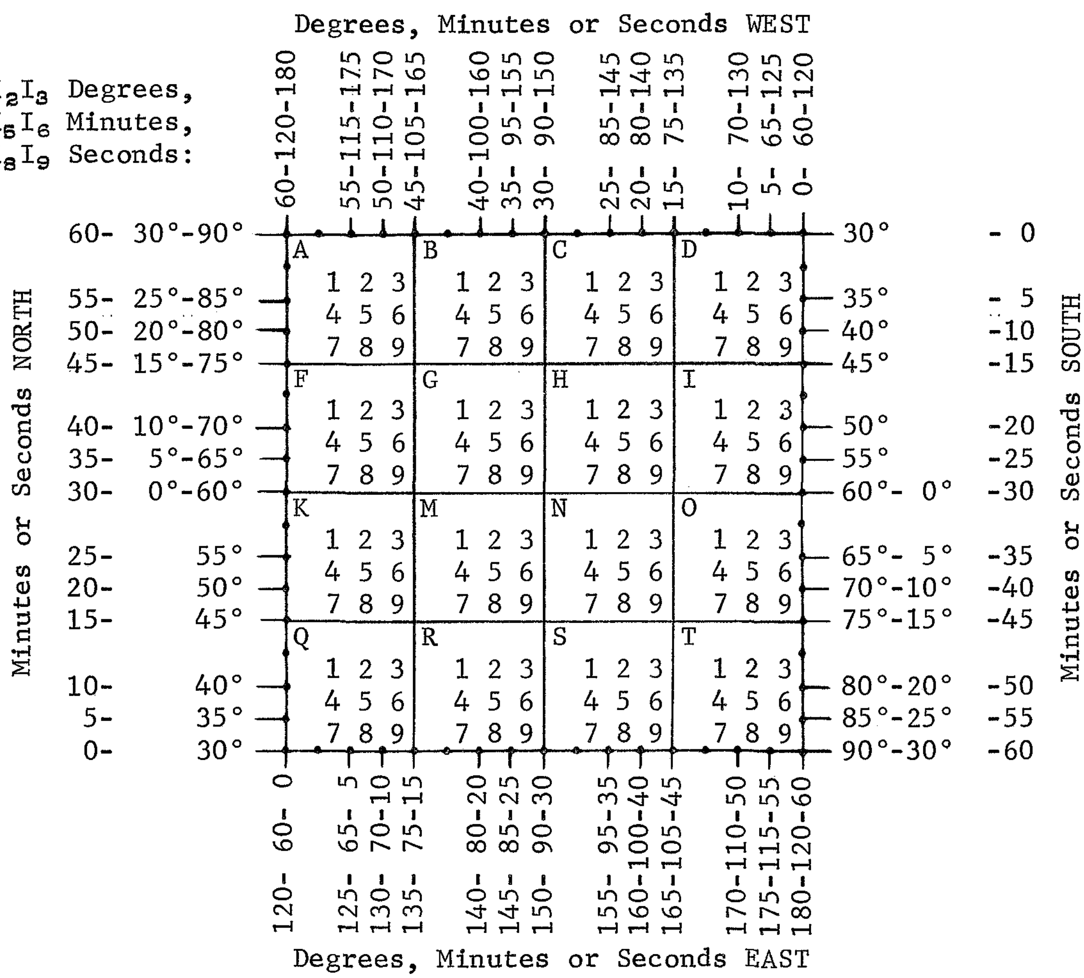
I_1



I_4 Degrees,
I_7 Minutes,
I_{10} Seconds:



I_2I_3 Degrees,
I_5I_6 Minutes,
I_8I_9 Seconds:



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1. "The Character of Gravispheres", Thomas C. Ensign and John C. Bellamy, Information Circular No. 36; NRRI, University of Wyoming; Oct. 1965, 35 pp.

2. "Some Notes on Marine Meteorological Observations", Dick M. Whiting, Memorandum, National Weather Records Center, Asheville, N.C.; April 1969, 6 pp.

3. "Grid System", R. W. Titus, Memorandum to File; Operations Branch, ESSA Atmospheric Research Laboratory, Las Vegas, Nev.; July 10, 1967, 10 pp.

4. "An Ordinance Establishing a Land Office for the United States", Thomas Jefferson, Congress of the United States, April 25, 1784.

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